SIX-NUCLEON SPECTROSCOPIC AMPLITUDES FOR 1p-SHELL NUCLEI. PART 2. CALCULATIONS AND APPLICATIONS

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Spectroscopic amplitudes for separation of six-nucleon clusters in low-lying states corresponding to the $(1s)^4(1p)^2$ shell-model configuration were calculated for 1p-shell nuclei. The calculations were performed with the aid of intermediate-coupling model wave functions. The selectivity in excitation of the states produced in six-nucleon cluster transfer reactions with 1p-shell nuclei is discussed. Sum rules for six-nucleon pickup and stripping are given.

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1. Introduction

Multinucleon transfer reactions are the useful tools for investigations of the multinucleon cluster structure of light nuclei. The study of the six-nucleon clusterization of 1p-shell nuclei via transfer reactions seems to be fruitful because of a relatively simple structure of six nucleon clusters [1]. They can be found in a few low-lying states. Therefore it is probable that the six-nucleon transfer may proceed with excitation and coherent contribution of these low-lying cluster states to the differential cross section. In order to answer the question whether the six-nucleon clusterization of 1p-shell nuclei exists the calculations of the absolute values of the cross sections, e.g. on the basis of direct reaction model,

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have to be performed. For this purpose the spectroscopic amplitudes (SA's) for the low-lying six-nucleon cluster states in 1p-shell nuclei have to be known.

In Section 2, a method of calculation of six-nucleon SA's for 1p-shell nuclei is presented. The states of nuclei considered are represented by the intermediate-coupling model wave functions [2, 3]. The six-nucleon fractional parentage coefficients (FPC's) given in Part 1 of this work [4], play a substantial role in the present calculations. In Section 3, the sum rules for six-nucleon SA's are formulated as well as the selectivity of excitation of final states produced in six-nucleon transfer reactions in discussed. Finally conclusions are given in Section 4.

2. *Method of calculations*

Multinucleon spectroscopic amplitudes (SA's) can be defined by a simple generalization of the definition of alpha-particle SA's [5]. In this work the definition from Ref. [6] has been used

$$S_{nLJ}^{A(B,C)} = \binom{A}{C}^{1/2} \langle \phi_{E_A J_A T_A}^{A} | (\phi_{E_B J_B T_B}^{B} \times (\varphi_{nL}(\boldsymbol{R}_{B,C}) \times \phi_{E_C J_C T_C}^{C})^{JT_C})^{J_A T_A} \rangle, \tag{1}$$

where ϕ^i is the antisymmetric internal wave function of the nucleus i ($i = A, B$ or C[1]) being in the state labelled by the energy level E_i, spin J_i and isospin T_i (in what follows the third components of angular momenta and isospins are suppressed), $\varphi_{nL}(\boldsymbol{R}_{B,C})$ is the wave function of the relative motion between the core nucleus B and the cluster C labelled by the number of nodes n and the angular momentum L. The order of coupling of angular momenta is shown by the parentheses, i.e. $\boldsymbol{J} = \boldsymbol{L}+\boldsymbol{J}_C$, $\boldsymbol{J}_A = \boldsymbol{J}_B+\boldsymbol{J}$ and $\boldsymbol{T}_A = \boldsymbol{T}_B+\boldsymbol{T}_C$.

In practice, instead of the complicated internal wave functions ϕ^i their counterparts, i.e. the shell-model wave functions ψ^i are applied. But these functions contain a centre of mass (c.m.) motion of the nucleus in the average shell-model potential well. If the shell-model wave functions ψ^i are expanded in the harmonic oscillator shell-model (h.o.s.m.) basis, the separation of the c.m. motion from ψ^i is straightforward. Thus ψ^i can be expressed as a product of two terms: the internal wave function ϕ^i and the wave function $\phi_{00}(\boldsymbol{R}_i)$ of c.m. motion (i.e. with no quanta of the c.m. motion) [7]. Due to this property and making use of the generalized Talmi-Moshinsky transformation [8] the formula (1) reads [6, 9]

$$S_{nLJ}^{A(B,C)} = \left(\frac{A}{A-C}\right)^{\frac{2n+L}{2}} \binom{A}{C}^{1/2} \langle \psi_{E_A J_A T_A}^{A} | (\psi_{E_B J_B T_B}^{B} \times (\varphi_{nL}(\boldsymbol{R}_C) \times \phi_{E_C J_C T_C}^{C})^{JT_C})^{J_A T_A} \rangle, \tag{2}$$

where $\phi_{E_C J_C T_C}^{C}$ is the internal part of the h.o.s.m. wave function $\psi_{E_C J_C T_C}^{C}$ and R_C defines the c.m. position of the cluster C with respect to the centre of potential well. From the energy conservation law one has: $2n+L = Q_A - Q_B - Q_C$ ($n = 0, 1, 2, \ldots$), where Q_A, Q_B and Q_C are the numbers of oscillator quanta for nuclei A, B and C, respectively.

[1] Depending on the context A, B and C label the nuclei or stand for their mass numbers.

In what follows the SA's for a separation of the six-nucleon cluster, belonging to the $(1s)^4(1p)^2$ shell-model configuration, from 1p-shell nuclei will be considered.

The calculations of SA's are divided into two parts: (a) for $10 \leqslant A \leqslant 16$ where they can be performed with the aid of six-nucleon FPC's for the 1p-shell [4], (b) for $A < 10$ where 1p-shell nucleons do not suffice to build up the six-nucleon cluster and therefore 1s-shell nucleons should be taken into account.

2.1. $(1s)^4(1p)^{n\geqslant 6} \rightarrow (1s)^4(1p)^{n-1} + (1s)^4(1p)^2$ partition

The intermediate-coupling model wave functions of low-lying normal parity states of 1p-shell nuclei [2, 3] can be expanded in terms of the following h.o.s.m. basis $\psi((1s)^4(1p)^n [f]\alpha LS; JT)$, where $\boldsymbol{J} = \boldsymbol{L}+\boldsymbol{S}$. One obtains

$$\psi^i_{E_iJ_iT_i} = \sum_{\varrho_i=[f\varrho_i]\alpha\varrho_iL\varrho_iS\varrho_i} C(\varrho_i)\psi((1s)^4\,(1p)^n\,[f\varrho_i]\alpha\varrho_iL\varrho_iS\varrho_i;\, J_iT_i), \tag{3}$$

where $\varrho_i = (k, l, m)$ for $i = (A, B, C)$. The expansion coefficients $C(\varrho_i)$ result from a diagonalization procedure with the intermediate-coupling model Hamiltonian (see for instance Ref. [2]). Dealing with these wave functions Eq. (2) takes the form

$$S^{A(B,C=6)}_{nLJ} = \sum_{k,l,m} C(k)C(l)C(m)S^{A(B,C=6)}_{nLJ}(k, l, m), \tag{4a}$$

where

$$S^{A(B,C=6)}_{nLJ}(k, l, m) = \left(\frac{A}{A-6}\right)^{\frac{2n+L}{2}} \left(\frac{A}{6}\right)^{1/2}$$

$$\times \langle \psi((1s)^4\,(1p)^{A-4}[f_k]\alpha_kL_kS_k;\, J_AT_A|\,(\psi((1s)^4(1p)^{B-4}[f_l]\alpha_lL_lS_l;\, J_BT_B)$$

$$\times (\varphi_{nL}(\boldsymbol{R}_C) \times \psi((1s)^4\,(1p)^2\,[fm]\,\alpha_mL_mS_m;\, J_CT_C))^{JT_C})^{J_AT_A}\rangle. \tag{5}$$

Adapting the results of Smirnov and Tchuvilsky [10] for the case of six-nucleon SA's the formula (5) reads

$$S^{A(B,C=6)}_{nLJ}(k, l, m) = \left(\frac{A}{A-6}\right)^{\frac{2n+L}{2}} \binom{A-4}{6}^{1/2} \frac{\sqrt{10}}{6} (\dim [f_m])^{-1/2}$$

$$\times \sum_{|L-L_m|\leqslant\mathscr{L}\leqslant L+L_m,\alpha_m} U(LL_mJS_m;\, \mathscr{L}J_C)\hat{L}_k\hat{S}_k\hat{J}_B\hat{J} \begin{Bmatrix} L_l & S_l & J_B \\ \mathscr{L} & S_m & J \\ L_k & S_k & J_A \end{Bmatrix}$$

$$\times \langle \mathrm{p}^{A-4}[f_{pk}]\alpha_kL_kS_kT_A|\mathrm{p}^{B-4}[f_{pl}]\alpha_lL_lS_lT_B,\, \mathrm{p}^6[f_m]\alpha_m\mathscr{L}S_mT_C\rangle$$

$$\times \langle \mathrm{p}^6[f_m]\alpha_m\mathscr{L}|\mathrm{p}^4[4]L,\, \mathrm{p}^2[f'_m]L_m\rangle, \tag{4b}$$

where $\langle \mathrm{p}^{A-4}|\mathrm{p}^{B-4}, \mathrm{p}^6\rangle$ and $\langle \mathrm{p}^6|\mathrm{p}^4, \mathrm{p}^2\rangle$ are the six-nucleon [4] and two-nucleon [11] orbital FPC's for the 1p-shell, respectively;

$$U(LL_mJS_m;\, \mathscr{L}J_C) = (-1)^{L+L_m+J+S_m}\hat{\mathscr{L}}\hat{J}_C \begin{Bmatrix} L & L_m & \mathscr{L} \\ S_m & J & J_C \end{Bmatrix},$$

$\begin{Bmatrix} LL_m\mathscr{L} \\ S_mJJ_C \end{Bmatrix}$ and $\begin{Bmatrix} L_lS_lJ_B \\ \mathscr{L}S_mJ \\ L_kS_kJ_A \end{Bmatrix}$ the $6j$ and $9j$ coefficients for recoupling of angular momenta, $\hat{L} = \sqrt{2}L+1$, and dim $[f_m]$ the dimension of the representation $[f_m]$. The Young diagrams $[f_{pk}]$ ($[f_{pl}]$) are the counterparts of diagrams $[f_k]$ ($[f_l]$) corresponding to 1p-shell nucleons merely and $[f'_m] = [2]$ ($[11]$) for $[f_m] = [42]$ ($[411]$).

The SA's of Eqs. (4a, b) were calculated with the aid of program AMPL [12]. The six-nucleon and two-nucleon orbital $\langle p^6|p^4\,[4], p^2\rangle$ FPC's were taken from Part 1 of this work [4] and Ref. [11], respectively. The wave functions (and excitation energies) of nuclei were obtained by means of the program SHELL [13] using 2BME (for $A \leqslant 9$) and (8–16) POT (for $A > 9$) interactions of Cohen and Kurath [3]. The calculations of SA's were performed for the ground and five lowest excited states of ^{6}Li cluster (the ^{6}Li

TABLE I

Six-nucleon spectroscopic amplitudes for pickup from ^{12}C target. First column shows the angular momentum J and isospin T of a given state of the final nucleus. The calculated excitation energy E is in the second column. The spectroscopic amplitudes for different orbitals of the transferred cluster are specified by the number of nodes n, angular momentum L and spin J. The transferred cluster states are specified by the spin, parity, isospin and the calculated excitation energy of the ^{6}Li nucleus

Transfer of ^{6}Li$(1^+, 0)_{g.s.}$

J T	E [MeV]	$n=2$	$n=1$			$n=0$
		S_1	D_1	D_2	D_3	G_3
1 0	0.0	−0.658	0.099			
	5.06	0.140	0.288			
2 0	5.22			0.318		
3 0	2.13				0.441	−0.057

Transfer of ^{6}Li$(3^+, 0)_{2.13[MeV]}$

J T	E [MeV]	$n=2$	$n=1$			$n=0$		
		S_3	D_1	D_2	D_3	G_1	G_2	G_3
1 0	0.0		0.441			−0.057		
	5.06		−0.101			−0.426		
2 0	5.22			0.187			−0.506	
3 0	2.13	−0.630			0.669			0.649

Transfer of ^{6}Li$(0^+, 1)_{2.50[MeV]}$

J T	E [MeV]	$n=2$	$n=1$
		S_0	D_0
0 1	2.50	0.805	
2 1	6.03		−0.788

TABLE I (continued)

Transfer of $^6Li(1^+, 0)_{5.06[MeV]}$

$J\ T$	E [MeV]	$b = 2$ S_1	$n = 1$ D_1	$n = 1$ D_2	$n = 1$ D_3	$n = 0$ G_3
1 0	0.0	0.140	0.288			
	5.06	−0.259	−0.098			
2 0	5.22			−0.194		
3 0	2.13				−0.101	−0.426

Transfer of $^6Li(2^-, 0)_{5.22[MeV]}$

$J\ T$	E [MeV]	$n = 2$ S_2	$n = 1$ D_1	$n = 1$ D_2	$n = 1$ D_3	$n = 0$ G_2	$n = 0$ G_3
1 0	0.0		−0.318				
	5.06		0.194				
2 0	5.22	−0.342		0.187		0.304	
3 0	2.13				−0.186		0.506

Transfer of $^6Li(2^+, 1)_{6.03[MeV]}$

$J\ T$	E [MeV]	$n = 2$ S_2	$n = 1$ D_0	$n = 1$ D_2	$n = 0$ D_2
0 1	2.50		−0.788		
2 1	6.03	0.614		−0.344	1.200

cluster states with the isospin $T = 1$ correspond to the ground and first excited states of ^{6}He and ^{6}Be clusters). Numerical values of these amplitudes can be obtained from one of the authors (E.K.) upon request. For example, in Tables I and II the six-nucleon SA's for pickup from ^{12}C and stripping on ^{7}Li targets are presented.

2.2. $(1s)^4\,(1p)^{n<6} \rightarrow (1s)^{n_1} + (1s)^4\,(1p)^2$ partition

Six-nucleon SA's for nuclei with the mass number $A < 10$ can be calculated taking into account one of two possibilities of formation of the six-nucleon cluster: (*i*) it is build up from all 1p-shell and a few 1s-shell nucleons, (*ii*) it is what is left after taking off a $n_1 = A-6$ nucleon cluster from a nucleus A. The calculation of six-nucleon SA's for the case (*i*) is complicated [10] and requires the knowledge of recoupling coefficients for the SU(4) group [14] which are tabulated only for some cases (see for instance Ref. [15]). However, the relation between the considered SA's and for the reversed partition (i.e. $A(C = 6, B = n_1)$ instead of $A(B = n_1, C = 6)$) of the nucleus A can be simply derived (see Appendix) taking into consideration the possibility (*ii*) of formation of the six--nucleon cluster. According to this relation (Eq. (A2)) the amplitudes $S_{A(B=n_1, C=6)}$ can

TABLE II

Six-nucleon spectroscopic amplitudes for stripping on ^{7}Li target. See caption to Table I

Transfer of ^{6}Li$(1^+, 0)_{g.s.}$

J T	E [MeV]	$n=2$ S_1	$n=1$ D_1	$n=1$ D_2	$n=1$ D_3	$n=0$ G_3	$n=0$ G_4
1/2 1/2	0.0	−0.039	0.060	−0.110			
	8.78	0.019	0.105	−0.165			
3/2 1/2	3.59	0.041	−0.050	0.064	−0.093	−0.014	
	10.43	−0.064	−0.004	0.065	−0.044	−0.007	
5/2 1/2	7.40	0.024	−0.105	−0.058	0.009	−0.052	−0.070

Transfer of ^{6}Li$(3^+, 0)_{2.13[MeV]}$

J T	E [MeV]	$n=2$ S_1	$n=1$ D_1	$n=1$ D_2	$n=1$ D_3	$n=1$ D_4	$n=0$ G_1	$n=0$ G_2	$n=0$ G_3	$n=0$ G_4
1/2 1/2	0.0		0.044	0.274			−0.087	−0.153		
	8.78		−0.082	0.041			−0.030	0.203		
3/2 1/2	3.59	−0.274	−0.037	−0.027	0.445		0.032	−0.047	0.062	
	10.43	0.046	0.105	0.007	−0.076		−0.093	−0.147	0.137	
5/2 1/2	7.40	0.048	−0.005	−0.138	−0.179	−0.080	0.133	0.243	0.297	0.158

Transfer of ^{6}Li$(0^+, 1)_{2.50[MeV]}$

J T	E [MeV]	$n=2$ S_0	$n=1$ D_0	$n=0$ G_0
1/2 1/2	0.0		0.177	
	8.78		−0.017	
3/2 1/2	3.59	0.131	−0.086	
	10.43	−0.083	0.037	
5/2 1/2	7.40		0.045	0.095

Transfer of $^{6}Li(1^{+}, 0)_{5.06[MeV]}$

J T	E [MeV]	$n=2$ S_1	$n=1$ D_1	$n=1$ D_2	$n=1$ D_3	$n=0$ G_3	$n=0$ G_4
1/2 1/2	0.0	−0.072	0.073	−0.166			
	8.78	0.166	−0.257	−0.131			
3/2 1/2	3.59	0.001	−0.038	0.012	0.109	−0.042	
	10.43	−0.200	0.245	0.117	0.051	−0.018	
5/2 1/2	7.40	0.041	0.030	0.013	0.093	−0.111	−0.014

Transfer of $^{6}Li(2^{+}, 0)_{5.22[MeV]}$

J T	E [MeV]	$n=2$ S_2	$n=1$ D_1	$n=1$ D_2	$n=1$ D_3	$n=1$ D_4	$n=0$ G_2	$n=0$ G_3	$n=0$ G_4
1/2 1/2	0.0	−0.231	0.075	0.250			0.009		
	8.78	−0.011	−0.312	−0.035			0.075		
3/2 1/2	3.59	−0.002	0.011	−0.016	−0.265		0.029	0.068	
	10.43	0.008	0.293	0.075	−0.051		−0.133	−0.066	
5/2 1/2	7.40	0.137	0.013	−0.176	−0.138	0.017	0.038	−0.025	−0.039

Transfer of $^{6}Li(2^{+}, 1)_{6.03[MeV]}$

J T	E [MeV]	$n=2$ S_2	$n=1$ D_0	$n=1$ D_1	$n=1$ D_2	$n=1$ D_3	$n=1$ D_4	$n=0$ G_2	$n=0$ G_3	$n=0$ G_4
1/2 1/2	0.0	0.268		−0.108	−0.685			0.087		
	8.78	0.035		−0.020	−0.056			0.047		
3/2 1/2	3.59	−0.320	−0.078	<0.001	0.368	0.041		−0.098	−0.054	
	10.43	0.009	0.067	−0.002	−0.015	0.065		−0.035	−0.089	
5/2 1/2	7.40	−0.116		<0.001	0.146	0.243	0.015	−0.189	−0.412	−0.195

be expressed by means of a linear combination of the amplitudes $S_{A(C=6,\,B=n_1)}$ which for some cases are collected elsewhere [16–20] or can be simply calculated according to well known methods [9, 21].

3. *The selectivity in excitation of states produced in six-nucleon cluster transfer reactions*

The selectivity in excitation of nuclear states produced in multinucleon transfer reactions depend on the nuclear structure and the mechanism of reactions [6]. In the present work this problem is discussed from the nuclear structure point of view only, in the case of the six-nucleon cluster transfer.

The selectivity in excitation should be reflected by the percentage distribution of the total strength among states populated in multinucleon transfer reactions [18]. The total strength is equal to the sum of all squared SA's for all final states described by the nuclear structure model involved. It can be calculated by an explicite summation or with the aid of the sum rule for pickup.

3.1. Sum rules

The sum rules for six-nucleon SA's considered in Subsection 2.1 can be defined similarly as in the case of one to five-nucleon SA's for 1p-shell nuclei[2] [16–20]. These sum rules can be applied for a prediction of the population of low-lying final states. Besides this they can also serve as a check of numerical calculations. The sum rules for SA's of Subsection 2.1 were derived taking into account the well known orthonormality relations [21] of the orbital and isospin-spin six-nucleon FPC's [4]. Moreover, these orbital and isospin-spin FPC'S fulfil reciprocal relations adequate for the SU(3) and SU(4) Clebsch-Gordan coefficients [22, 15], respectively. They were applied in derivation of the sum rule for stripping.

The sum rule for six-nucleon SA's for pickup is

$$\sum_{J_B T_B J_C T_C L J} (S_{nLJ}^{A(B,C=6)})^2 = \tfrac{5}{18}\left(\frac{A}{A-6}\right)^4 \binom{A-4}{6} \sum_{k,[f_0]} C^2(k)\, \frac{\dim [f_0]}{\dim [f_{pk}]}, \tag{6}$$

where the summation on the left-hand side runs over all states of the nucleus B and cluster C and over quantum numbers of the angular momentum L and spin J of cluster orbitals, $C(k)$ are the expansion coefficients of the wave function of the target nucleus A. The summation on the right-hand side includes all $[f_0]$ for which $[f_{pk}]$ appears in the products $[f_0] \times [42]$ and $[f_0] \times [411]$. The sum rule for stripping is

$$\sum_{J_A T_A J_C T_C L J} \left(\frac{\hat{J}_A \hat{T}_A}{\hat{J}_B \hat{T}_B}\, S_{nLJ}^{A(B,C=6)}\right)^2 = \tfrac{5}{18}\left(\frac{A}{A-6}\right)^4 \binom{A-4}{6}$$

$$\times \sum_{l} C^2(l)\, \frac{\dim [f_{pl}]}{\dim (\lambda_l \mu_l)\, \dim [\widetilde{f_{pl}}]} \sum_{[f_0]} \frac{\dim (\lambda_0 \mu_0)\, \dim [\widetilde{f_0}]}{\dim [f_0]}, \tag{7}$$

[2] The six-nucleon SA's of Subsection 2.2 fulfil the sum rules identical with those for one to five-nucleon SA's [16–20].

where dim $(\lambda\mu)$ and dim $[\tilde{f}]$ are the dimensions of the SU(3) and SU(4) group representations, respectively. Once $[f]$ is known these dimensions are determined uniquely. The second sum on the right-hand side of Eq. (7) includes all $[f_0]$ which appear in the product $[f_{pl}] \times [42]$ and $[f_{pl}] \times [411]$.

3.2. The selectivity

The fraction of the total strength deposited in a given final state origins from all six-nucleon cluster states taking part in the transfer process. Usually, only a few low-lying cluster states participate in excitation of the final state. Figs. 1–3 illustrate the distributions of the total strengths among states produced by the six-nucleon cluster transfer for three selected cases. Fig. 1 illustrates the pickup from ^{12}C target. It can be seen that 84% of the total strength lies in the six lowest states of the $A = 6$ nucleus. The most prominent first $(J^\pi, T) = (2^+, 1)$ state (32% of the total strength) is excited by the transfer of the two lowest $(0^+, 1)$ and $(2^+, 1)$ cluster states. The example of pickup from ^{13}C target is given in Fig. 2. In this case only 32% of the total strength is distributed among the five lowest final states of ^{7}Li (or ^{7}Be). In excitation of the most prominent first $(7/2^-, 1/2)$ state the two six-nucleon cluster states dominate: $(3^+, 0)$ and $(2^+, 1)$. The first $(1/2^-, 1/2)$ state can-

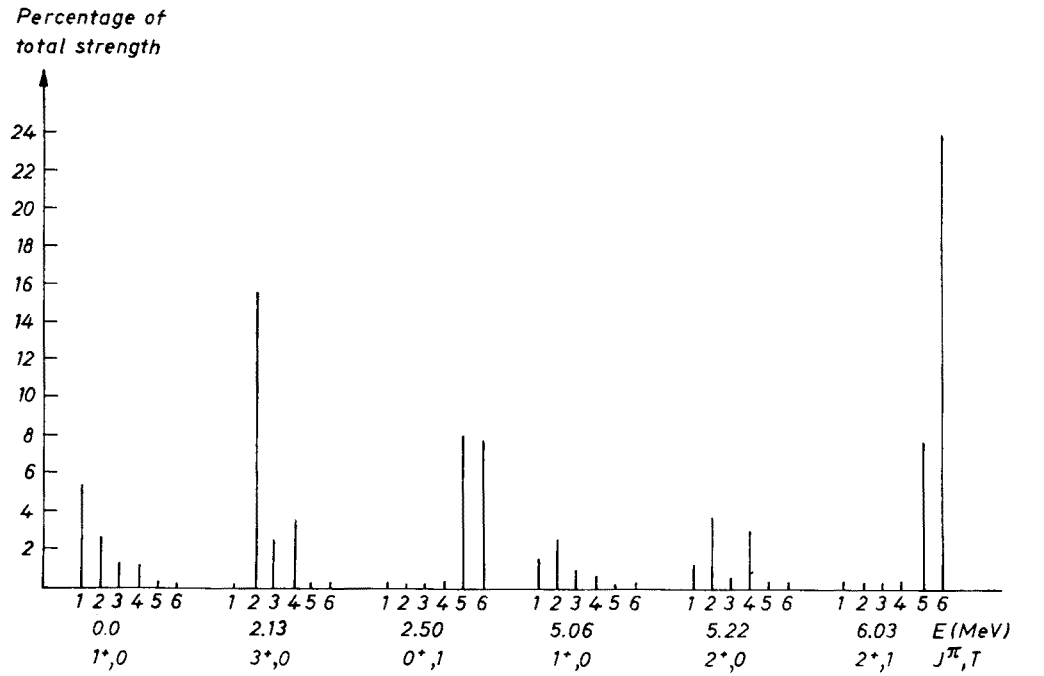

Fig. 1. The distribution of the total strength among states produced by pickup of six-nucleon clusters from the ^{12}C target. Final states are specified by the spin J, parity π, isospin T and calculated excitation energy E. The six-nucleon cluster states specified by the spin, parity and isospin are numbered according to the increasing calculated excitation energy (in MeV) for $T = 0$ and $T = 1$ states of ^{6}Li, respectively: *1* — $(1^+, 0; 0.0)$, *2* — $(3^+, 0; 2.13)$, *3* — $(1^+, 0; 5.06)$, *4* — $(2^+, 0; 5.22)$, *5* — $(0^+, 1; 2.50)$, *6* — $(2^+, 1; 6.03)$

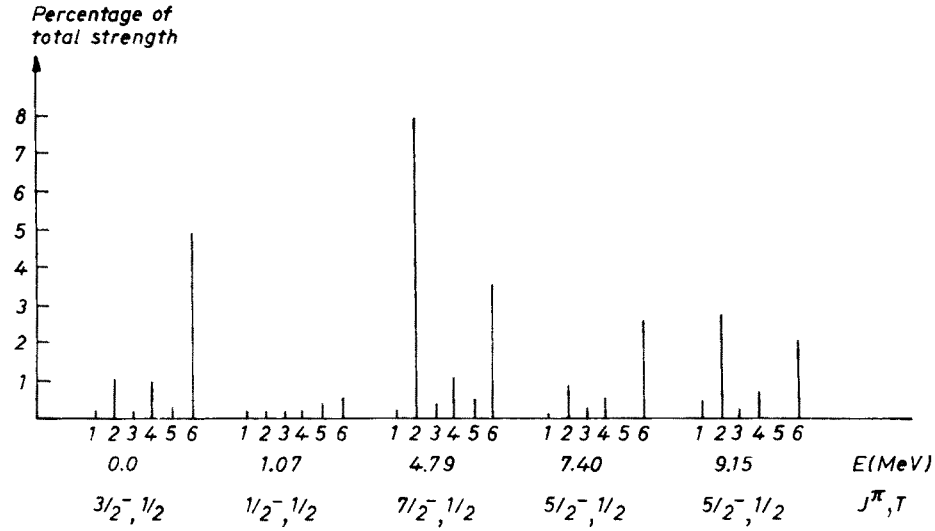

Fig. 2. The distribution of the total strength among states produced by pickup from the ^{13}C target. See caption to Fig. 1

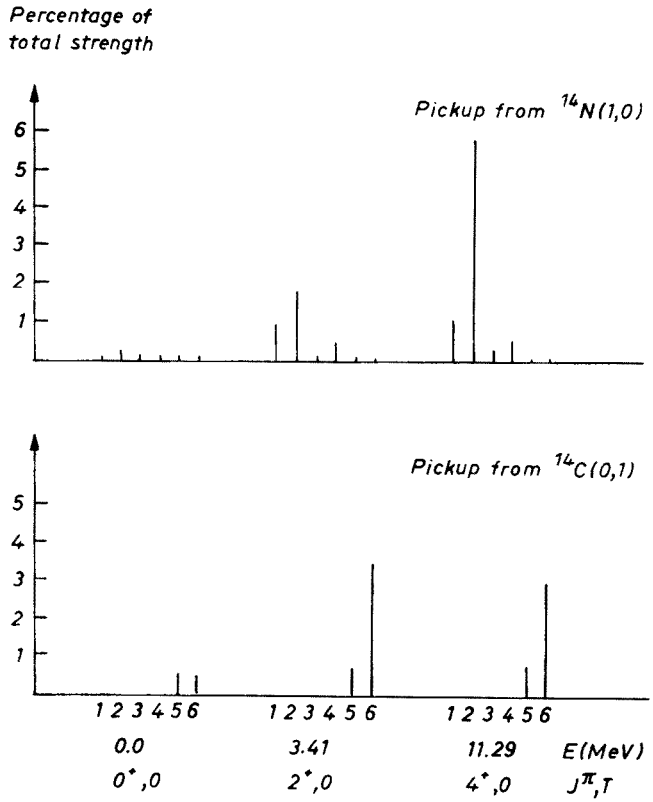

Fig. 3. The comparison of excitation rotational-like states of ^{8}Be by pickup from the ^{14}N and ^{14}C targets. See caption to Fig. 1

not be probably observed (only 1 % of the total strength). A comparison of excitation of the three rotational-like states of ^{8}Be by pickup from ^{14}N and ^{14}C targets is given in Fig. 3. It is seen that in pickup from these targets the ground state of ^{8}Be probably cannot be produced. The intensity of the state $(4^+, 0)$ excited in pickup from ^{14}N is twice as large as in pickup from ^{14}C.

4. *Summary*

In the six-nucleon cluster transfer reactions a new substantial problems emerge which were not present in a few nucleon transfer reactions. The six-nucleon clusters can be transferred in a few low-lying states with no hole excitations on the contrary for example to the alpha cluster. Examples discussed in Section 3 point out that these states, first of all, have to be taken into account in description of six-nucleon cluster transfer reactions. Figs. 1–3 show that for many cases no more than two or three cluster states prevail, so the remaining ones may be neglected. In general the total strength is distributed among wider energy range of final states as compared with the three [18], four [19] and five-nucleon [20] cluster transfer. But still a considerable fraction is concentrated in a few low-lying states.

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APPENDIX

Analogously to Eq. (1) one can define the SA's for the partition of nucleus A into core C and cluster B, i.e.

$$S_{nLJ'}^{A(C,B)} = \binom{A}{C}^{1/2} \langle \phi_{E_A J_A T_A}^{A} | (\phi_{E_C J_C T_C}^{C} \times (\varphi_{nL}(\boldsymbol{R}_{C,B}) \times \phi_{E_B J_B T_B}^{B})^{J' T_B})^{J_A T_A} \rangle . \tag{A1}$$

Assuming that in both definitions (Eqs. (1) and (A1)) nuclei A, B and cluster C remain in the same states, the SA's defined by Eq. (1) can be expressed by SA's of Eq. (A1). Making use of the U-recoupling coefficients one obtains

$$S_{nLJ}^{A(B,C)} = (-1)^{2L+J_C+J_B-J_A+T_C+T_B-T_A} \sum_{J'} U(J_B L J_A J_C; J' J) S_{nLJ'}^{A(C,B)}. \tag{A2}$$

So, the SA's for separation from the nucleus A a complex multinucleon cluster C can be calculated by means of the SA's for separation a less complex cluster $B = A - C$.

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There is wrong value of the weight factor in Table I on page 880. The correct value should read $\langle [441]||[3], [42]\rangle = \sqrt{\frac{3}{28}}$.